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Characteristics of the Ozone Exchange between the Troposphere and the Stratosphere

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Abstract

The ozone mixing ratio data from 1958 to 2001 from ECMWF was used to calculate global ozone transport and analyze the spatial-temporal distribution of the ozone transport. The results are as followings: (1) The intensity of ozone transport enhances from the upper troposphere to the lower stratosphere and reaches the highest value at 30hPa and then it decreases. The ozone vertical transport is mainly from the stratosphere to the troposphere. The OUT (ozone upward transportation) is mainly over the ocean, while the ODT (ozone downward transportation) is mainly over the mainland and there is a strong and perennial ODT center over the Eurasian Continent. (2) The ozone transportation varies with the season, and its intensity is the strongest in winter and weakest in spring. It is relatively weak in autumn and in summer. And it is mainly in the northern hemisphere in winter and in spring, while it is mainly in the southern hemisphere in autumn and in summer. (3) There is a clear about 20-year period variability of the ozone transportation below 20hPa.

Keywords: stratosphere, ozone transportation, troposphere- stratosphere exchange

1.Introduction

Ozone distribution is mainly in the stratosphere at the altitude from 10 to 50 km, it can strongly absorb the ultraviolet radiation. The ozone exchange between the troposphere and the stratosphere plays an important role in the climate change. Generally speaking, ozone content in the stratosphere is higher than that in the troposphere. Ozone inflow from the stratosphere to the troposphere leads to the morphological structure change of ozone vertical profile[1, 2], which causes the change of the atmospheric chemistry forcing and atmospheric radiation. Many Chinese scholars have done a lot of researches on ozone. By analyzing the ozone mixing ratio grid data, Wang Weiguo et al[3] studied the spatial-temporal evolution of

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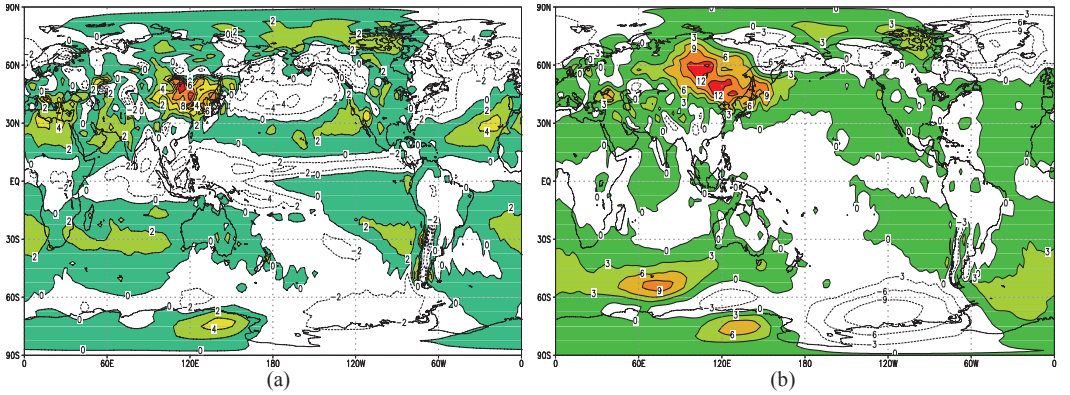
ozone flux between the global stratosphere and the thermosphere. Guo Shichang et al[4] discussed the relationship between the activity of East Asian summer monsoon and the change of ozone content in the tropopause. Yang Jian et al[5] and Cong Chunhua et al[6] respectively researched the ozone quality exchange between the troposphere and the stratosphere with NCEP data. Wang Gengchen et al[7] revealed the ozone change characteristics in the tropopause in Beijing, which had an effect on the atmospheric ozone content in the upper troposphere and in the lower stratosphere. Zheng Xiangdong et al[8] observed the total ozone of Lasa in 1998 and its vertical profile with the ozone radiosonde data. Bian Jianchun et al[9] studied the seasonal variation characteristics of the inertio-gravity wave in the lower stratosphere(17~24km) according to the new generation of radio sounding of vertical and high resolution data in Beijing observatory. Wang Weiguo et al[10] used the balloon borne instruments of electrochemistry ozonesonde to study ozone vertical distribution and its structure over Kunming in spring in 2001. Zhou Renjun et al[11] studied the vertical distributions and variation characters of ozone over the Iranian Plateau by using the TOMS，HALOE and SAGE Ⅱ data.

By using the ECMWF data of the ozone mixing radio and the vertical wind, the global ozone exchange between the troposphere and the stratosphere was interviewed in this paper.

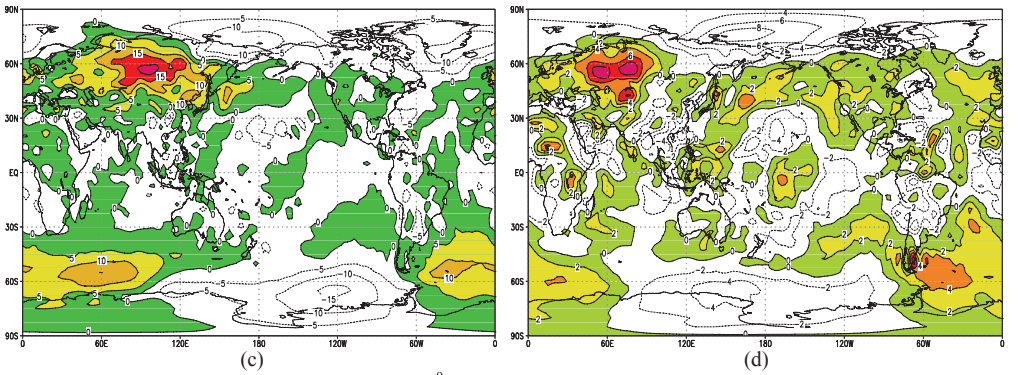
2.Data and methods

ECMWF data of the ozone mixing radio from 1958 to 2001 and the vertical velocity are used in this paper. Ozone vertical transportation means ozone mixing ratio multiplied by vertical velocity. Owing to the ozone transportation direction is in accordance with the vertical velocity. when ozone transportation value is positive, ozone transports downward (Ozone Downward Transportation，ODT) and when ozone transportation value is negative, ozone transports upward(Ozone Up Transportation，OUT).

3.Space distribution of ozone transportation



(a) (b)



(c) (d)

Fig.1 Space distribution of ozone transportation (units: 10^{-9}Pa/s) (a) 200hPa (b) 100hPa (c) 30hPa (d) 5hPa

Fig 1 shows the space distribution of mean ozone vertical transportation from 1958 to 2001 at 200hPa, 100hPa, 30hPa and 5hPa. It can be found that the intensity of ozone transportation enhances from the upper troposphere to the lower stratosphere, reaching the highest value in the middle stratosphere at about 30hPa and then it decreases. And the OUT is mainly over the ocean, while the ODT is mainly over the mainland. There is a strong and perennial ODT center over the Eurasian Continent.

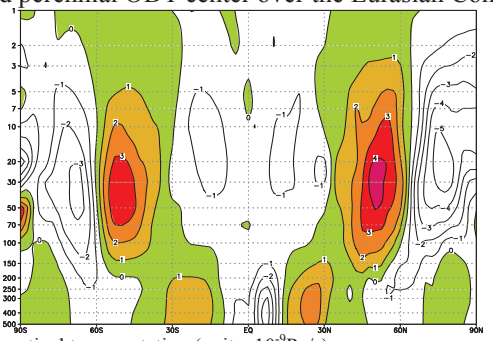


Fig. 2 Vertical–zonal profile of ozone vertical transportation (units: 10^{-9}Pa/s)

In order to highlight the longitudinal variation of ozone transportation, Fig 2 exhibits the vertical–zonal profile of ozone transportation. The intensity of ozone transportation in northern hemisphere is higher than that in southern hemisphere. OUT mainly centers in the low latitudes and high latitudes, while ODT centers in the middle and low latitudes from the upper troposphere to the lower stratosphere. The ozone transportation has obvious zonal features in different layers. The intensity of ozone vertical transportation presents a trend that it first enhances and then falls off, which is weaker in the middle and upper troposphere, unusually stronger in the lower and middle stratosphere and then weaker in the upper stratosphere.

4.Seasonal distribution of ozone transportation

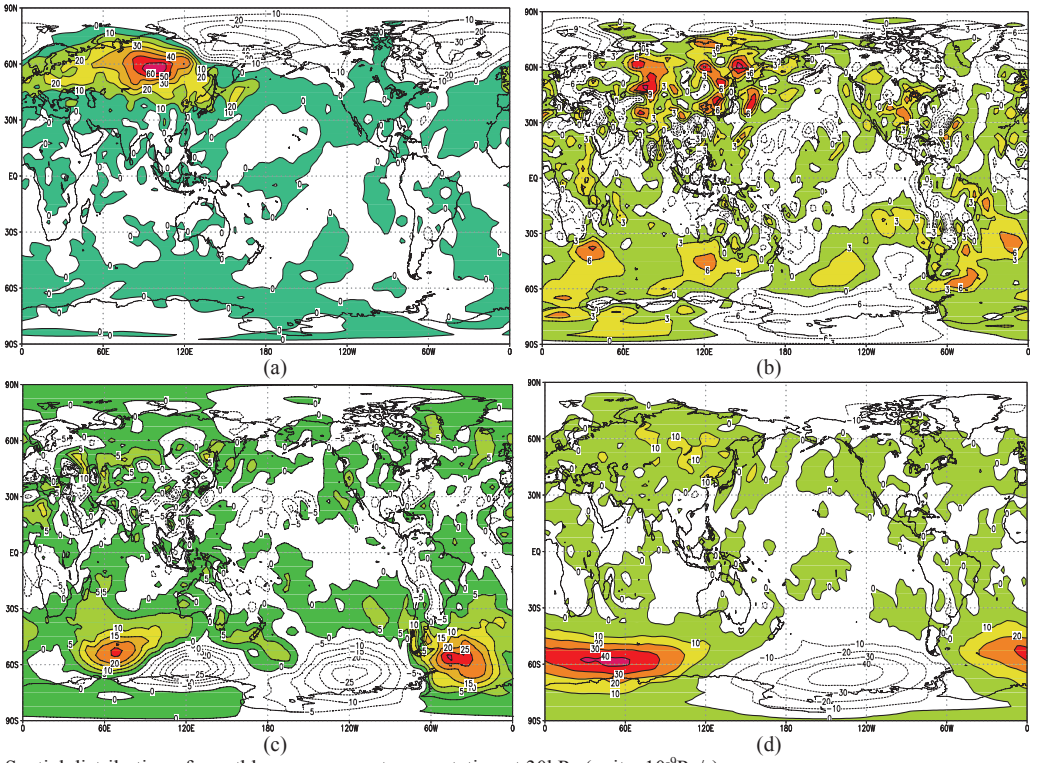


Fig. 3 Spatial distribution of monthly mean ozone transportation at 30hPa (units: 10^{-9}Pa/s)
(a) January (b) April (c) July (d) October

The above analysis indicates that ozone vertical transportation of ozone is the strongest at 30hPa. Fig 3 shows the spatial distribution of monthly mean ozone vertical transportation at 30hPa. In winter, ozone transportation is in middle and high latitudes in northern hemisphere. The OUT mainly spreads over the northern Pacific, Arctic Ocean and Greenland, the ODT mainly spreads over the Eurasia. In Spring, Ozone transportation in northern hemisphere is slightly stronger than that in southern hemisphere, its distribution is very dispersed, the intensity of the ODT area is still the highest in Eurasia, followed by the north American continent, the Indian Ocean and the Atlantic. In summer, ozone transportation develops and gathers from the northern hemisphere to southern hemisphere, whose strong center mainly locates in middle and high latitudes in southern hemisphere. The OUT is mainly over the southeast Indian Ocean and South Pacific; the ODT is mainly over the southwest Atlantic and south Indian Ocean. In autumn, ozone transportation is still mainly in middle and high latitudes in southern hemisphere. The OUT is mainly over the southwest and southeast Pacific; the ODT is mainly over the southwest Atlantic and south Indian Ocean. In conclusion, ozone transportation focuses mainly in northern hemisphere in winter and spring, while it mainly focuses in southern hemisphere in summer and autumn. It concentrates in autumn and winter, which disperses in summer. Besides, the intensity of ozone transportation is the strongest in winter, the rank of the other three seasons' intensity in descending order is: autumn, summer and spring.

5.Interannual and interdecadal change of the global net ozone transportation

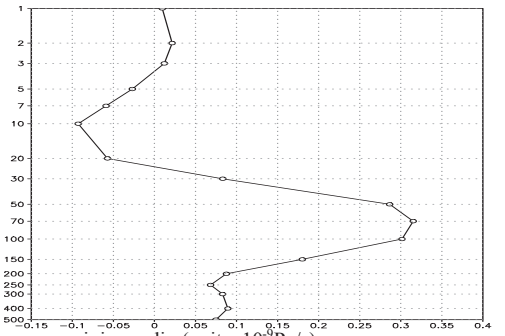


Fig. 4 Vertical profile of global mean ozone mixing radio (units: 10^{-9}Pa/s)

The global mean ozone net transportation was calculated by averaging the global ozone transportation. Fig 4 shows the vertical profile of global mean ozone mixing radio from 1958 to 2001. It can be perceived that the vertical ozone transportation has a remarkable difference with the altitude. The vertical ozone transportation is positive below 30hPa, while it is negative from 30hPa to 3hPa. Ozone transport is weaker above 3hPa. The maximum value of the ODT is at about 70hPa and the ODT is at about 10hPa. In general, the ozone vertical transportation is mainly from the stratosphere to the troposphere.

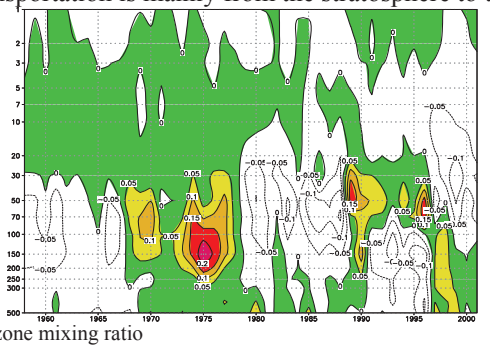


Fig 5 Departure of the global net ozone mixing ratio
(units: 10^{-9}Pa/s)

Fig5 depicts the departure of the global net ozone mixing ration. It can be perceived that the intensity of ozone transportation is very different in different years. This phenomenon mainly represents below 20hPa. From the mid 1950s to the late 1960s, the vertical transportation of ozone is relatively weaker, whose anomalies are negative. It is higher from the late 1960s to the middle and late 1990s. And the vertical transportation of ozone is weaker in the late 1980s. From the late 1980s to the middle 1990s, it enhances above 100hPa while decreases below 100hPa. At the beginning of this century, it is weaker again above 100hPa. It is obvious that there is a 20-year period variability.

6.Conclusions

By using the ECMWF data, the global ozone distribution and exchange are interviewed. The conclusions are as followings:

- From the upper troposphere to the upper stratosphere, the intensity of ozone transportation first enhances, it is the highest at 30hPa. Then it decreases. The OUT is mainly over the ocean, while the ODT is mainly over the mainland and there is a strong and perennial ODT center over the Eurasian Continent.
- Ozone transportation focuses mainly in the northern hemisphere in winter and spring, while it mainly focuses in southern hemisphere in summer and autumn. It concentrates in autumn and winter, which disperses in spring and summer. Besides these, the intensity of ozone transportation is the strongest in winter.
- The vertical ozone transportation has a remarkable difference in vertical direction. The maximum value of the ODT is at about 70hPa and the ODT is at about 10hPa. The ozone vertical transportation is mainly from the stratosphere to the troposphere.
- There is a obvious interannual and interdecadal change of the global net ozone transportation below 20hPa. Its variation period is about 20-year.

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